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LABORATORY STUDIES OF MOUNTAIN STRUCTURES.

(A REPORT OF PROGRESS.)

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Several investigators have used the compression box type of machine for the study of mountain structures in the laboratory, but so far as I know, no one else has used a machine of such dimensions as that constructed by Stone, with the face of the thrust block at an angle other than ninety degrees to the direction of thrust (1). My first investigations were begun using a modification of this machine in order to study structures produced by thrusting, the thrust being transmitted by the advance of a thrust block the face of which was at an angle of forty-five degrees to the direction of thrust. Since starting the work it has seemed advisable to study the results obtained by the use of the unmodified machine as well as those obtained by the use of the modified machine (2).

The materials used are layers of clay to represent incompetent strata and paraffine to represent the competent strata. In the early stages of our work at Muskingum College, Stone experimented with Plaster of Paris for the competent layers, but found it too brittle and faulted rather than folded. In all my work I have used pure paraffine for the competent strata. As the paraffine layers represent the competent strata their thickness is an important factor and will be given in all cases.

In these studies the blocks to be compressed were built of two layers of clay separated by a paraffine layer and capped by another paraffine layer. An overburden of sand was piled on top to give pressure corresponding to the weight of younger strata and the block was shortened seven inches. In the earlier stages of our work various combinations of clay and paraffine

layers were used and in no case was any attempt made at uniformity of thickness of the individual paraffine layers. These layers varied from paper thin to three-sixteenths of an inch in thickness. In all cases the thrust was transmitted by a block the face of which advanced at an angle of forty-five degrees to the direction of thrust. Later experiments were tried, and are still being tried, in which uniformity of paraffine layers has been maintained. In some cases the thrust is transmitted by a block the face of which advances at an angle of forty-five degrees to the direction of thrust and in other cases the face of the block advances at ninety degrees to the direction of thrust.

Some of the experiments are here described and tentative conclusions drawn from the results. We are continuing these studies and plan to carry on field studies in connection with our laboratory experiments in the hope that we might get more definite results, but we are of the belief that some of our preliminary results and tentative conclusions may be of interest.

For the sake of clearness in describing the results let us suppose that the thrust comes from the east, then the side of the block opposite the thrust will be the west. Thus we can speak of the various portions of the block in terms of direction.

A block was made in which the lower paraffine layer varied from three-eighths of an inch in thickness at the south side of the block to paper thin at the north side of the block. The top layer of paraffine was of similar thickness.

On the side of the block nearest the thrust, where the paraffine was thickest, the layers folded once into an asymmetrical anticline having its steeper side next to the thrust. The crest of the anticline broke thus causing a fault to develop. On the west side of the block, where the paraffine layers were thick, the layers rode up on the confining wall. Toward the north side of the block, near the thrust, a series of small asymmetrical folds developed. This seems to indicate that the thrust was transmitted much better by the thick layers than by the thin ones.

Across the block at the west side, where the paraffine layers were thin, the top layer broke into a series of asymmetrical folds which were parallel to the face of the thrust block. It will be noted by reference to Figure 1 that these folds are slightly arcuate.

Another block was formed in which the bottom paraffine

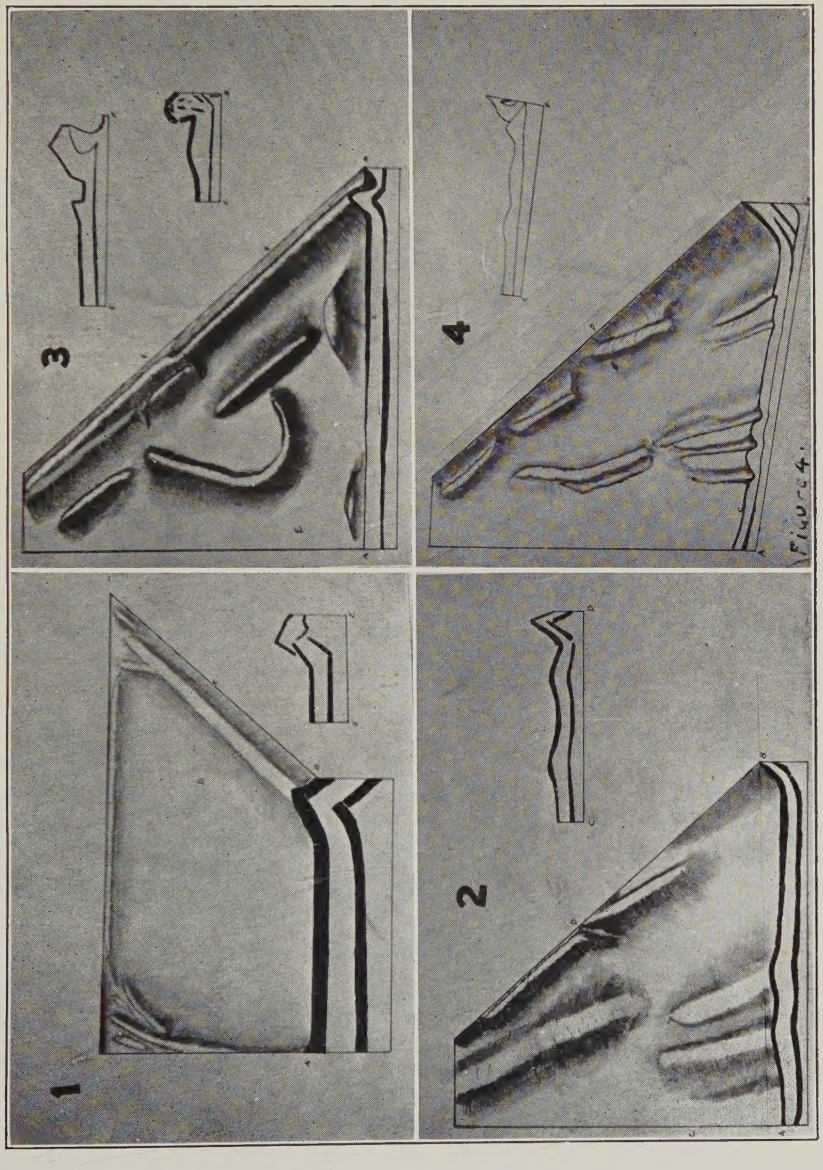
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Figure 4.
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layer was from three-sixteenths of an inch to one-quarter of an inch in thickness. The top layer varied from one-eighth of an inch to five-sixteenths of an inch in thickness, thickening toward the thrust block.

On the south-east side of the block the layers rode up on the thrust block. Farther north along the thrust block an asymmetrical anticline developed having its steeper side next the thrust block. Beginning about the place where this anticline developed a symmetrical anticline developed parallel to the face of the thrust block and at a distance from it. Near the south-west corner of the block a series of folds developed parallel to the face of the thrust block.

These results indicate that where the competent layers are thick the thrust is transmitted easily and a few larger folds result. (Figure 2.)

In another block the bottom layer of paraffine varied from one-eighth of an inch to five-sixteenths of an inch in thickness, being thinner near the thrust block. The top layer was paper thin on the west side, thickening to three-eighths of an inch at the east side.

On the east side of the block, where the paraffine layer was thickest, the layers were folded into an asymmetrical anticline the steeper side of which was to the west. At the south-east corner of the block a large asymmetrical syncline formed, the steeper side of which was away from the thrust. On the limb of the anticline near the thrust, in the top paraffine layer, a series of five small folds were formed. These folds amounted to small wrinkles on the surface of the paraffine and were due to the compression of the layer into a smaller area. Toward the north-east corner of the block, where the paraffine was thin, a series of small asymmetrical folds were formed parallel to the face of the thrust block.

Midway across the block, with one end joining the previously described anticline at a point where the anticline breaks into several folds, was a hook-shaped anticline resembling a large reversed J. This developed only on the surface layer. The steeper side of this fold was toward the east. The peculiar shape of the fold was probably due to the force resultant of the several forces acting—the active thrust and the stationary blocks. From the barb of the hook-like anticline there extended a small asymmetrical anticline parallel to the face of the thrust block. (Figure 3.)

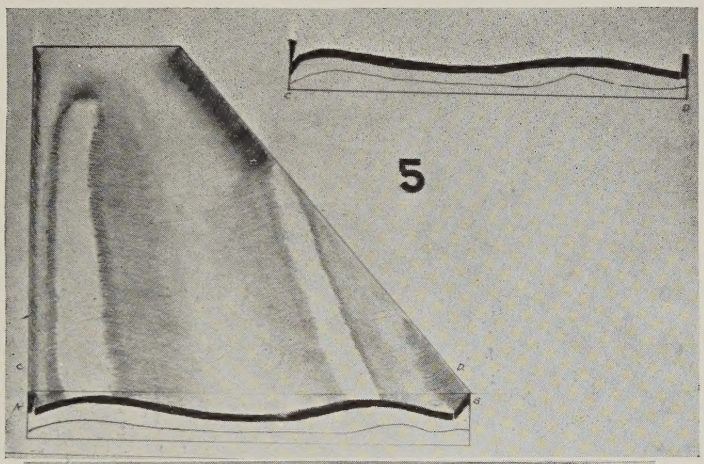
A block in which the basal paraffine layer varied from three-sixteenths of an inch to paper thin and the top layer of which varied from one-sixteenth of an inch to paper thin was subjected to a thrust similar to that to which the other blocks were subjected.

Along the east side of the block the layers folded upward riding up on the thrust block. The fold was broken on the flank by a series of smaller folds having the steeper side toward the west. Because the competent layers were too thin to transmit the thrust for any great distance the folds broke into a number of smaller ones. Near the south-east side of the block a series of small folds developed in the top layer. These folds made an angle with the face of the thrust block joining the upthrust portion about fourteen inches from the south side of the block. About half way across the block, in the top layer, there was a series of parallel folds almost parallel to the face of the thrust block but making a slight angle with it. These folds were low and small. They parallel the face of the thrust block for a short distance then swing around parallel to the west wall of the machine. Note that this fold curves. (Figure 4.) The bottom layer of paraffine was unaffected except by slight thickening at the ends of the block and faulting near the thrust block.

Another block was deformed in a similar way. This block was built as the others but the bottom paraffine layer was paper thin and the top paraffine layer varied from a quarter to a half inch in thickness. (Figure 5.)

Near each end of the thrust block the thick paraffine layer rode up on the block. At a distance of about five inches from the thrust block, measured along the south edge, a large, gentle fold developed at an angle to the face of the thrust block and meeting it about eighteen inches from the south-east corner of the block. Across the block near the west wall an asymmetrical anticline developed having the steeper side away from the thrust. The paraffine layer rode up on the west wall. The bottom paraffine layer had a few small folds and faults not coincident with those above. This experiment shows that the thrust is best transmitted by the thicker layers and that folds are fewer in number and of greater magnitude.

As has already been suggested some of our later experiments have been carried on using both the modified and unmodified machine with special effort being made to maintain uniformity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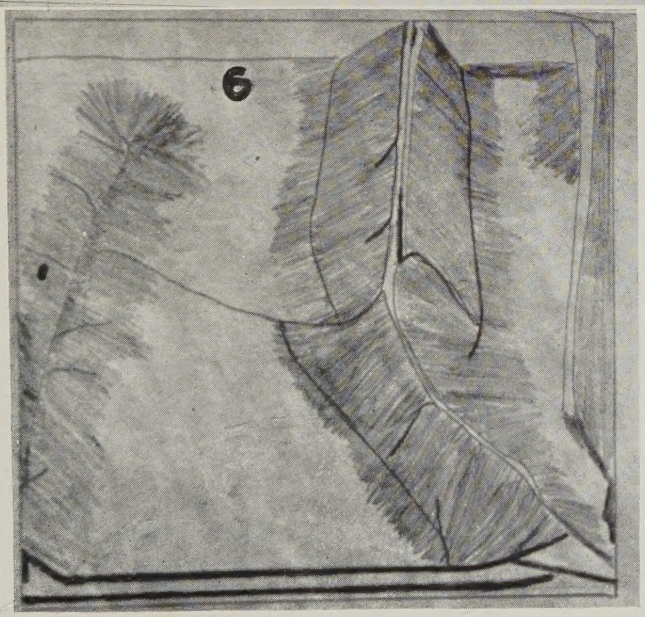
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of thickness of the individual paraffine layers. We are at present engaged in such studies varying the thickness of the paraffine layers and trying various combinations in order to find, if possible, the mathematical relationship between thickness of competent layers and number and magnitude of folds.

In one of these experiments the paraffine layers were five-sixteenths of an inch in thickness. The block was shortened eight inches by the advance of a thrust block the face of which advanced at an angle of ninety degrees to the direction of thrust.

The layers rode up on the thrust block. An arcuate anticline formed three inches from the thrust block along the south side and nine and one-half inches from the thrust block at the north side. Along the west wall a small fold formed having its steeper side toward the west. All these folds were greatly faulted. One fault developed along the crest of the anticline and numerous others at right angles down the limbs of the folds. (Figure 6.)

A number of arcuate folds were formed both in blocks in which no effort was made to maintain uniformity of competent layers as well as in blocks where uniformity was maintained. They formed in blocks which were compressed in the modified machine and those which were compressed in the unmodified machine.

The experiments here described are a few of those performed but they serve to illustrate some of the results from which the following tentative conclusions have been drawn. There seems to be a relationship between the thickness of the competent layers and the number and magnitude of the folds. Exactly what this relationship is we cannot state with mathematical accuracy, but our results seem to indicate that where the competent layers are thick a few large folds are formed and where the competent layers are thin numerous small folds develop. At present we are carrying on investigations using competent layers of uniform thickness in the hope of discovering the mathematical relationship between the thickness of the competent layers and the number and magnitude of the folds.

These experiments also show that even though the top layers are deformed the bottom layers do not necessarily deform in a similar manner but may find relief by thickening. This may be due to the additional weight of the strata above or the fact that the lower layers may be in the zone of flowage.

The factors influencing the character, location and magnitude of folds are therefore:

1. Thickness and competency of the layers involved.
2. The forces or combination of forces involved in producing the folds.
3. The overburden.

Unfortunately, studies of this sort are suggestive rather than conclusive. As Stone suggested to the Geology section at the 1930 meeting of the Ohio Academy of Science, we cannot reproduce field conditions to scale in the laboratory because field investigators have failed to give us the needed data as to crushing and tensil strengths of the rocks involved in such structures. If we had such data we might reproduce on a small scale observed geologic structures and arrive at some conclusions as to their mode of origin.

LITERATURE CITED.

1. **Stone, Alan.** Science, Vol. LXXII, No. 1863, Sept. 12, 1930, p. 276.
2. **Mitchell, R. H.** Science, Vol. LXXII, No. 1863, Sept. 12, 1930, pp. 275–76.

Spectroscopy.

This book is highly recommended to those who wish to have, in an interesting and convenient form, a discussion of the apparatus, technique and data involved in the study of Spectroscopy. The book fills a long felt need for an introductory text on this subject which might be easily understood by scientists in other fields (particularly in Analytical, Organic and Bio-Chemistry). The author suggests method of procedure together with examples of data and their interpretation. There is an absence of a suitable bibliography; and an overemphasis of the author's personal contributions detract slightly from the volume.

—WALLACE R. BRODE.

Spectroscopy, by S. Judd Lewis. 91 pp. London, Blackie and Son, Ltd., 1933.

Petroleum.

Here are brought together the results of five years research carried on at various places in the United States upon material collected from all over the world. There are dealt with in the various chapters the following major subjects: collection and preparation of samples; measurement of organic content; distillation tests; texture; calcium carbonate content; relation of organic matter to environment; detailed analyses of organic constituents of sediment; change in organic content with depth; comparison of past and recent sediments; and theoretical considerations. It is a definite contribution to the understanding of the possible origin of the source beds of petroleum.—WILLARD BERRY.

Origin and Environment of Source Sediments of Petroleum, by P. D. Trask, assisted by H. E. Hammar and C. C. Wu. xv+323 pp. Houston, Gulf Publishing Co., 1932. $6.00.

PRELIMINARY STUDY OF THE RELATION BETWEEN THERMAL EMISSIVITY AND PLANT TEMPERATURES.*

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Whenever a plant leaf is exposed to radiant energy from a source such as the sun this energy has three modes of dissipation: (1) reflection from the surface of the leaf, (2) absorption by the leaf, (3) transmission by the leaf. The quantitative value of the first varies with the nature of the receiving surface and the wavelength of the incident radiation. The value of the second varies with the nature and thickness of the absorbing tissue and the wavelength and intensity of the radiation. The amount of energy transmitted depends upon the wavelength of the radiation, the transparency and diathermancy of the leaf tissue. Of the three named possibilities of energy dispersal the second only is capable of raising the temperature of the leaf tissue and is the subject of investigation in these experiments.

In general, the leaf tissue will absorb solar energy of the period to excite the molecular vibration within the tissue concerned. The energy absorbed is mostly in the form of longer waves many of which are in the visible spectrum. These waves suffer a degradation of energy content and are emitted from the tissue as waves of a lower refrangibility.

The energy absorbed by a leaf may be dissipated in the following ways:

1. Thermal emission (radiation and conduction to the air).
2. Conduction to internal tissue of lower temperature.
3. Transpiration.
4. Photochemical reactions (photosynthesis and others). Respiration, an exothermic reaction, is also taking place and needs to be evaluated.

RELATIVE IMPORTANCE OF DISPERSAL METHODS.

Investigations have shown the thermal unimportance of respiration and photosynthesis in considering plant temperatures. Miller (5) in a review of the literature, says the values for the percent of incident radiation used in photosynthesis range from .5% to 7.7%. However, the more recent experi-

*Papers from the Department of Botany, The Ohio State University, No. 317.

ments, Miller (6); Putter, as quoted by Spoehr (9); and Transeau (10) place the amount at less than 4%. The latter has calculated his results for corn on the basis of the total available energy per acre over a 100-day growing season in the vicinity of central Illinois. He also found that of the total available energy, only .5% was returned to the environment by respiration. Brown and Escombe (1) say that a respiring *Liriodendron tulipifera* leaf comes into thermal equilibrium with its surroundings at .019° C. In the following experiments the thermal exchanges of respiration and photochemical reactions have been neglected as insignificant.

The dissipation of heat energy by conduction to internal tissue of lower temperature has no significance in the cases where the substance is partially diathermanous or is sufficiently thin to become practically uniformly heated throughout. The latter is the case in all of the following experiments.

The poor thermal conductivity of succulent tissue may be significant in the prevention of killing by heat or frost of desert cacti which are exposed for a few hours to extreme temperature conditions. Such may be the case in the larger succulents such as *Carnegia gigantea* under conditions of intense insolation. Conduction through tissue of high specific heat and low diathermancy must be responsible for part of the cooling of the surface. A rather steep gradient of temperature is probably maintained between the internal and external tissues.

Transpiration has long been considered one of the most important methods of energy dispersal by the leaf tissue. Brown and Escombe (1) working with *Helianthus annuus*, concluded that transpiration accounted for 80% of dispersal of available energy and therefore considered this process very important as a means of energy dissipation. Shull* (8)

*Shull gives figures part of which were taken from the work of Brown and Escombe, in which the incident radiation is .8 cal. per sq. cm. per min.; the coefficient of absorption is 65%; the mass beneath a sq. cm. of leaf surface is .02 gms. and the specific heat is .879. With these figures, and assuming no energy dispersal he calculates the rate of temperature rise of the leaf to be 29.6 degrees per min. But Brown and Escombe also say that a moderate rate of thermal emission is .014 cal. per min. per sq. cm. of leaf surface for each degree temperature difference.

Using these figures we see:

$$\frac{.8 \times .65}{2 \times .014} = 18.5 \text{ C.}^\circ$$

Thus the leaf would come into thermal equilibrium with its environment at a temperature 18.5 C.° above the environment and the rate of temperature rise equal to 29.6 C.° per min. holds at no time except when there is no temperature difference between the leaf and the air.

said, "There is no doubt that transpiration is vitally necessary, and that its chief function is energy dispersal."

Clum (3) has performed an exhaustive series of experiments to determine the cooling power of transpiration. As a result of his investigations, he concludes, "The review of the literature shows that the temperature of plant tissues is usually higher than that of the air in bright sunlight, but is subject to wide and rapid fluctuations. From the available evidence, however, the cooling effect of transpiration seldom exceeds 2 or 3 C. degrees."

Miller and Saunders (7) made over one thousand determinations of leaf temperatures of soy beans, corn, sorghum, cowpeas and alfalfa growing under field conditions in Kansas. They found no significant difference between air and leaf temperatures. They also found that the temperature of wilted leaves above that of turgid leaves in sunlight varied from 2 to 6 C. degrees.

As a result of these and other similar investigations, showing that at best transpiration could account for only a few degrees of cooling in leaf tissue, and since the range of temperature differences used varied from 3 to 30 C. °, the temperature effects of transpiration have been neglected in these experiments.

McDougal (4) using a clinical thermometer thrust into the tissue of a prickly pear cactus found that it attained a temperature of 31° F. above air temperature, that elongation continued even at 137° F., and that heating to 144° F. would not permanently injure the plant.

Clum (3) found that the presence of a large water content seemed to make little difference in the rapidity of temperature fluctuations, noting that the fresh leaf fluctuated as rapidly and over as wide range as the dried one. My own results do not agree with this as I found small but consistently greater emissivity values for dried leaves than for fresh ones of higher water content.

Brown and Wilson (2) have investigated the effects of thermal emission on plant temperatures. Proceeding on the assumption that a leaf maintained at a temperature above that of the surrounding air will lose heat at the same rate that a leaf maintained the same number of degrees below air temperature will gain heat, they were enabled, by the differential transpiration method to determine the rate of emission in terms of calories per unit of surface and time, and for a

one-degree temperature difference between the leaf and its surroundings.

Although these investigations involved a range of only two degrees, from 17° to 19° C., these authors conclude that, "The variation of the coefficient of emissivity with temperature can safely be neglected for any range of temperature to which the leaf may be subjected under natural conditions." The experiment was carried on with similar leaves from four different species and the results agreed very closely.

Clum (3), however, agrees with other investigators, that the leaf temperatures calculated from the emissivity formula of Brown and Wilson are consistently below those temperatures which have been observed by means of the thermocouple. The reason for this may lie in the method of determining leaf temperatures which Brown and Wilson used. The temperatures they recorded with their platinum resistance thermometers in contact with the leaf surface could at best record only the temperature of that surface and actually must have been somewhat influenced by the higher temperature of the surrounding air.

Even though the differential method was used, the thermometer which was at a lower temperature would be more influenced by the higher air temperature. Thus the heat which flowed into the plant per degree temperature difference was calculated to be greater than it probably actually was, with a consequent too great value for the emissivity factor.

Clum also notes that, ". . . the temperature of the leaf is so influenced by the intensity of the light that one can tell very little about the transpiration rate from the temperature and emissivity as calculated for leaves in the dark." That this is a legitimate criticism can be seen at once by noting the absurdity of the result obtained under certain conditions by the use of the formula which Brown and Wilson (2) proposed, viz.,

$$E = Qh/(\theta - \theta')$$

where E is emissivity, Q is grams of water lost, h is the latent heat of vaporization of water, and $(\theta - \theta')$ is the temperature difference between the leaf and air. One can readily conceive of a case where the radiant energy absorbed by a leaf would be just sufficient to carry on transpiration. Thus the temperature difference would be zero and emissivity would take on an infinite value.

APPARATUS.

The thermocouple set-up consisted of a mirror galvanometer used in conjunction with two junctions of copper and constantin wire. B&S Gauge 30 constantin wire and B&S Gauge 40 copper wire were soldered to form each junction. The constantin was introduced through a glass tube which had been drawn out to capillary size and then broken off back just far enough to permit a rather snug fit of the wire. This wire was allowed to protrude about two centimeters from the end of the glass capillary and copper wire was soldered to the constantin. The glass tube was carefully advanced upon the constantin until it just touched the soldered portion of the junction, the copper wire remaining on the outside. A piece of B&S Gauge 22 copper wire of sufficient length to reach a single pole switch was soldered to the No. 40 copper about five centimeters from the junction.

Another piece of tubing whose internal diameter was sufficient to hold the original tubing and the No. 22 copper wire was also drawn out to a fine capillary. This tube was then placed over the junction, enclosing the smaller tube, all of the No. 40 copper and about two centimeters of the end of the No. 22 copper wire. These were held firmly in position within the tube by means of sealing wax having a high melting point. None of the wax, however, was permitted to come into contact with the junction. The external tube was broken off so that both tubes ended at the junction, which was allowed to protrude about 1 mm. beyond the end of the glass. Construction of the couple with this fine wire permitted a junction to be used whose size caused a minimum of injury to the tissue into which it was inserted.

The galvanometer was the Leeds and Northrup type 2285-X.

As most of the thermal measurements were to be between 20° and 50° C., it was desired to have the reference junction somewhere within this range, and a method of keeping it at constant temperature. This was accomplished by allowing water to come into equilibrium with a 37.5° C. incubator. This water was then poured into a thermos bottle which had also been in the incubator for several hours and sealed with a single hole rubber stopper through which the reference junction, similar in construction to the one described above, was placed. This junction then remained within the incubator during the

course of the experiments. The actual temperature of this junction was determined by a zero galvanometer reading. The thermocouple was then calibrated, using a large standardized mercury thermometer graduated to 0.1° C. so that one cm. on the galvanometer scale corresponded to approximately one degree. Temperatures accurate to 0.1° C. could easily be read.

The heating element used in some of the experiments was the Rodale Straight Type Heating Element, similar to that used in many reflecting heaters. An ordinary metal reflecting lamp shade was placed around the element.

EXPERIMENTAL PROCEDURE.

According to definition, emissivity is the rate of thermal emission, or the number of calories lost per unit of time from a square centimeter of surface of a body for each degree of temperature difference between the body and its surroundings. In order then to know the corresponding temperatures to which the body will be subjected, it is necessary to know the mass, specific heat, and area of surface of that body.

The following experiments are, however, based upon rates of temperature loss, and the rate of cooling is expressed in terms of degrees lost per minute for each degree difference in temperature. A determination of rates of temperature loss provides a more significant as well as more accurate means of making comparison between leaf tissues from different plant species. It has the added experimental advantage that determinations can be made upon the tissue concerned while attached to the plant.

On all the plants the rate of thermal emission was calculated by observing the temperatures at equal intervals of time of a plant leaf which was cooling to room temperature, or rising from room temperature as a result of being placed in a constant temperature oven or exposed to radiation from the heating element. The results agree quite closely showing that absorption and emission are practically the same for any given temperature difference.

The rate of temperature loss for any temperature was found as follows: The leaf was heated by means of incident radiation from the heater element. The latter was mounted on the top of a revolving stool so that it could quickly be removed from the region of the plant by a half revolution of the stool top.

When the desired temperature difference was attained the

heater was removed and the leaf began to drop in temperature. Readings on the galvanometer were taken at 10-second intervals until the leaf had come into thermal equilibrium with its environment. The average temperature for two successive readings was found and subtracted from the equilibrium temperature. This was called the average temperature difference. The difference between successive readings gave the temperature drop during that 10-second interval. When multiplied by 6, this gave the rate of temperature loss per minute for the average temperature difference already determined.

A graph was then constructed using the average temperature differences as abscissae and the rates of temperature loss as ordinates. A comparison of the curves of a number of leaves of the same type, i. e., of the same species and maturity, from different plants not only showed very close agreement in rates of temperature loss, but above a temperature difference of 3 C.°, the curve was practically a straight line.

A straight line was then fitted to these data by the method of least squares. The result was a linear equation of the form

$$d\theta_t/dt = K\theta_t + b$$

where $d\theta_t/dt$ is the rate of temperature loss at time t, and θ_t is the temperature difference at time t. Since we know the rate of cooling must be zero when there is no temperature difference the value of 'b' is at once fixed at zero.

Therefore, the rate of cooling for any temperature difference above 3 C.° is proportional to the temperature difference multiplied by a constant 'K' which varies with the nature of the tissue.

DERIVATION OF THE GENERAL COOLING LAW.

It is desirable to investigate the general law of cooling which these tissues were found to follow.

Let θ_t be the temperature difference t seconds after leaf begins to cool.

Let $d\theta_t/dt$ be the rate of temperature loss at time t.

Let K be the constant whose value we seek.

Then the law of cooling is

$$d\theta_t/dt = -K\theta_t$$

or

$$\int d\theta_t/\theta_t = -K\int dt$$

whence

$$\log_e \theta_t = -Kt + \log_e c$$

where e is the base of the natural logarithms and $\log_e c$ is the constant of integration.
Then

$$\theta_t = c\, e^{-Kt}$$

We know that for 't' equal to zero

$$\theta_o = c$$

The constant 'c' is therefore determined to be numerically equal to the initial temperature difference, θ_o.

The rate of cooling after any time t has elapsed can be found by substituting the number of minutes for t in the following formula.

$$R_t = d\theta_t/dt = -\theta_o K\, e^{-Kt}$$

A comparison of cooling rates after any time interval t, for the same or different leaf tissues can then be made even if the initial temperature differences be not the same. In such a case the constant θ_o is made to correspond to the initial temperature differences for the respective tissues.

It remains then, to determine 'K' for tissues of varying degrees of succulence and water content.

DETERMINATION OF 'K' FOR FRESH LIRIODENDRON LEAVES.

Liriodendron tulipifera seedlings, three years of age, were transplanted from the garden into the greenhouse. They ranged in height from 1½ to 4 feet. Only mature leaves were used in the experiments. The junction of the couple was inserted into the mesophyll near the midrib. The insertion was placed on the under side of the leaf and care was taken to prevent its penetration into the upper epidermis upon which the radiation from the heating element was received.

The following series of experiments was performed. A different attached and mature leaf was used in each experiment. Leaves from three trees were used. Fourteen experiments were made in all.

1. Heated with element to 36° and allowed to cool to 22° C.
2. Heated with element to 35° and allowed to cool to 21° C.
3. Heated with element to 43° and allowed to cool to 24° C.
4. Heated with element to 29° and allowed to cool to 21° C.
5. Heated with element to 33° and allowed to cool to 22° C.
6. The heater was turned upon a leaf at about room temperature and the leaf was allowed to heat until the galvanometer showed an approximately uniform rate of rise. Readings at ten second intervals were then taken.

a. Heating from 33° to 44° C.
b. Heating from 31° to 38° C.

From these date the average value of 'K' and the probable error of the mean were found to be

$$K = 2.1 \pm .11$$

The equation of cooling for *Liriodendron tulipiera* is

$$d\theta_t/dt = -2.1\ \theta_t$$

and the temperature difference after any number of minutes 't' is

$$\theta_t = \theta_o\, e^{-2.1t}$$

where 'θ_o' is the initial temperature difference between the leaf and the air.

DETERMINATION OF 'K' FOR MESEMBRYANTHEMUM.

The plant used was *Mesembryanthemum crystallinum*. The leaves were in a turgid healthy condition. The thermocouple junction was inserted into the mesophyll so that radiation from the heater was allowed to fall upon the leaf on the side opposite that in which the insertion was made.

In these experiments the leaves were heated to about 40° C. and allowed to cool to equilibrium at 22° C. Temperature readings were taken each ten seconds during the cooling period. Four experiments were made. A different leaf from the same plant was used in each experiment. The average value of 'K' and the probable error of the mean are:

$$K = .45 \pm .02$$

The equation of cooling for *Mesembryanthemum* is

$$d\theta_t/dt = -.45\ \theta_t$$

and the temperature difference after any number of minutes 't' is

$$\theta_t = \theta_o\, e^{-.45t}$$

where 'θ_o' is the initial temperature difference between the leaf and air.

DETERMINATION OF 'K' FOR BYROPHYLLUM CALYCINUM.

The *Bryophyllum calycinum* leaves used were from plants which had reached maturity in the greenhouse. Four types of experiments were made, each with a different leaf.

1. Heated in incubator to 54° C. and allowed to cool to 24° C. in air. These leaves were detached from the plant.
2. Heated by heater element to 42° C. and allowed to cool to 24° C. The leaves were attached to the plant.
3. Detached leaf at 23° C. was placed in a 58° C. incubator and the rate of temperature rise of the leaf was taken at ten second intervals.
4. Attached leaf heated by element until uniform rate of rise was observed on the galvanometer. Initial recorded temperature 29° C., final temperature 45° C.

Eight experiments were made. The results of these were averaged and 'K' for fresh *Bryophyllum calycinum* was calculated from the formula. The average value of 'K' and the probable error of the mean were found to be

$$K = .38 \pm .02$$

The equation of cooling for *Bryophyllum calycinum* is

$$d\theta_t/dt = -.38\ \theta_t$$

and the temperature difference after any number of minutes 't' is

$$\theta_t = \theta_o\, e^{-.38t}$$

where 'θ_o' is the initial temperature difference between the leaf and air.

DETERMINATION OF 'K' FOR ECHEVERIA WEINBERGIA.

In these experiments mature and turgid leaves of *Echeveria weinbergia* were used. The junction was inserted into the mesophyll so that it lay about midway between the epidermal tissues. The leaf was heated to 48° C. by means of the heater element and allowed to cool to equilibrium temperature. Temperature readings were taken each ten seconds during the period of cooling. Six experiments were made, each with a different leaf on the same plant. The value of 'K' and the probable error of the mean were then calculated to be

$$K = .08 \pm .004$$

The equation of cooling for *Echeveria weinbergia* is

$$d\theta_t/dt = -.08\ \theta_t$$

and the temperature difference after any number of minutes 't' is

$$\theta_t = \theta_o\, e^{-.08t}$$

where 'θ_o' is the initial temperature difference between the leaf and air.

DETERMINATION OF 'K' FOR CEREUS.

The *Cereus* used was a four-ribbed rooted cutting, six inches high, which appeared in healthy condition. The thermocouple was inserted into the stem until the junction lay about midway between the epidermal tissues. The plant and junction were placed in the incubator whose temperature was 55° C., and the temperatures were recorded at intervals of one minute until equilibrium was reached. The plant was then taken from the incubator and allowed to cool in air and temperature readings were again taken each minute. From the series of eight experiments, four of the heating and four of the cooling type, the value of 'K' and the probable error of the mean were computed to be

$$K = .05 \pm .002$$

The equation of cooling for *Cereus* is

$$d\theta_t/dt = -.05\ \theta_t$$

and the temperature difference after any number of minutes 't' is

$$\theta_t = \theta_o\, e^{-.05t}$$

where 'θ_o' is the initial temperature difference between the stem and air.

EFFECT OF DESICCATION ON THE CONSTANT 'K.'

Having obtained the value of 'K' for several normal tissues, the effect of drying out on the rate of thermal emission could be put upon a quantitative basis.

Accordingly the following experiments were performed with *Liriodendron* and *Bryophyllum* leaves.

The junction was inserted into a leaf of *Liriodendron tulipifera* attached to the plant. Radiation from the heater element was then thrown upon the upper surface until a temperature of equilibrium at 40° C. was reached. The leaf was subjected to this temperature for one hour. At the end of this time several brown spots had appeared and the margin had begun to curl slightly. The heater was removed and temperatures of cooling were recorded at ten second intervals. Four experiments were made. The average value of 'K' was computed and found to be 2.5. This is about 19% above the value found for fresh leaves of the same species.

A leaf of *Bryophyllum calycinum*, attached to the plant, was heated by the heater element to 50° C. and maintained at that temperature for 90 minutes. One experiment was made. 'K' was calculated to be .45. This value is 18% greater than for the fresh leaf.

Another leaf of *Bryophyllum calycinum* was detached from the plant and suspended within a constant temperature oven at 55° C. for 26 hours. It was then removed and the temperature record of cooling was kept as before. Two experiments were made. The value of 'K' in this case was found to be .69. This is 80% above the value found for fresh leaves of the same species.

TEMPERATURE EFFECTS OF RESPIRATION AFTER INJURY.

Since injury to a tissue sometimes results in increased respiration it was desired to find the temperature effects of this increase caused by insertions of the thermocouple.

Three leaves of *Bryophyllum calycinum* each of which had been punctured in several places with the thermocouple were suspended near the top of a quart size thermos bottle. The thermocouple was inserted into the mesophyll of the second leaf. The bottle was filled with water at room temperature within three or four centimeters of the leaves and was then closed with a rubber stopper. This was done to saturate the atmosphere in which the leaves were suspended and thereby reduce heat losses by transpiration.

At the end of twenty minutes, no temperature change was noted. The temperature then began to rise slowly and at the end of four hours had reached a maximum of 1.3 C.° above air temperature.

However, of the experiments performed to determine the values of 'K,' none lasted more than one hour and twenty minutes, only one insertion of the thermocouple was made and there was no confinement permitting the accumulation of heat.

Thus, it is seen that under conditions which were more favorable to show temperature effects of respiration after injury than those obtaining during the determination of 'K,' no significant thermal effects were noted. The increased temperature effects of such respiration have therefore been neglected as insignificant.

EFFECT OF VASELINE UPON THERMAL EMISSIVITY.

Leaves of *Liriodendron tulipifera* and *Bryophyllum calycinum* were coated with a thin layer of vaseline over both surfaces and a redetermination of 'K' was made. In *Liriodendron* the layer of vaseline caused an 18% drop in the emissivity constant, while the constant for *Bryophyllum* was reduced by 13%.

In order to find the magnitude of the effect due to vaseline alone it was necessary to apply it to a plant tissue having a minimum of water loss. Therefore, the four ribbed cutting of *Cereus*, whose emissivity constant 'K' had already been determined to be .05 was entirely coated with vaseline and the value of 'K' again found. A decrease of 11% was noted.

Since the water losses in *Cereus* over the period of the experiment (one hour and twenty minutes) were insignificant, the 11% decrease in the value of 'K' must be due to the presence of the vaseline itself. If this be true, then complete prevention of transpiration causes a 2% drop in emissivity in *Bryophyllum* and 7% in *Liriodendron*. Thus the small portion of the value of 'K' which is due to transpiration is evident.

DISCUSSION.

It has been shown by these experiments what many recent investigators have suspected, viz., that the physical thermal properties exhibited by leaf tissue provide an adequate means of dispersal for excess radiant energy.

Even though Clum found that transpiration, at best, was responsible for only two or three degrees of cooling, while Transeau (10) computed 45% of the energy available per acre to be used in this work of evaporation, these results are not at all irreconcilable. The latter calculated his results for an acre of corn, the same plant which Miller and Saunders, in over a thousand determinations, found did not differ materially in temperature from that of the air. Because such a large percentage of energy was used in transpiration, it does not mean that the latter function was the mechanism which prevented the overheating of the tissue. It simply means that the rate and intensity of the incident radiation was just the correct amount to be almost entirely absorbed by the vaporization which was taking place. Had the intensity of the radiation been materially increased we would find that the physical thermal properties of the tissue and not transpiration would

prevent overheating. In the latter case, although transpiration would probably be slightly increased, it would consume a much smaller percentage of the available energy than in the situation noted above. It is, therefore, quite impossible to calculate the relative importance of transpiration as a cooling agent by observing the percentage of the available energy which it consumes.

In all of these experiments the rate of temperature loss only was determined.

But $dQ_t/dt = d\theta_t/dt \times a$

where dQ_t/dt is the rate of heat loss in calories at time 't'

$d\theta_t/dt$ is the rate of temperature loss in degrees at time 't'

a is a constant whose value is the product of the mass and specific heat of the tissue concerned.

If we wish to compare the rates of temperature loss of two types of tissues of known cooling rates, we have

$$\frac{d\theta_t'/dt}{d\theta_t/dt} = \frac{-K'\theta_t}{-K\,\theta_t} = \frac{K'}{K}$$

and the ratio becomes that of the cooling constants.

Cereus K = .05
Bryophyllum K = .38
Liriodendron K = 2.10

Thus *Bryophyllum* cools 7.6 times as fast as *Cereus*.

Moreover *Liriodendron* cools 5.5 times as rapidly as *Bryophyllum* and 42 times as fast as *Cereus*.

As an example of how the rate of temperature loss may be used to determine the absolute emissivity the following calculations for *Liriodendron tulipifera* were made.

K = 2.1
Mass of Leaf = .79 gms.
Total area of leaf = 70. sq. cms. × 2
= 140. sq. cms.

Using Brown and Escombe's value of .879 for the specific heat of the leaf, we are able to find the absolute emissivity per sq. cm. per unit temperature difference.

Thus

$$\frac{2.1 \times .79 \times .879}{140} = .010$$ cal. per sq. cm. per min. per degree temperature difference.

Brown and Wilson's calculations for this same species by the differential transpiration method gave the result .012 cal. per sq. cm. per min. per degree difference in temperature.

We can now calculate at what temperature the leaf would come into thermal equilibrium with its surroundings under the same still air conditions as were used to find 'K.'

The equilibrium temperature when the leaf is receiving on one surface incident radiation at the rate of .5 cal. per sq. cm. per minute and transpiring at the normal rate can be computed. Assuming the coefficient of absorption of the leaf to be .65, the equilibrium temperature would be.

$$\frac{.65 \times .5}{2 \times .010} = \begin{matrix}16.3\text{ C.}^\circ\text{ above air} \\ \text{temperature.}\end{matrix}$$

Clum, working with *Fuchsia speciosa*, *Phaseolus vulgaris*, *Brassica oleracea* and *Syringa vulgaris*, observed maximum temperatures to be 13° C. and 16° C. for the open field and greenhouse, respectively.

One fact appeared during the course of the experiments which appeared difficult to explain. At 3 C. ° temperature difference the value of 'K' fell off rather sharply and consistently in *Liriodendron* and only slightly less marked in *Bryophyllum*.

The average value of 'K' for *Liriodendron* over 13 trials was 1.8 as against 2.1 for temperature differences greater than 3 C.° In *Bryophyllum*, for eight trials, the drop in emissivity was noted from .38 to .35. No such drop appeared in four trials with *Cereus*.

There are two possible explanations:

1. A greater proportion of temperature loss is due to transpiration under a 3 C.° temperature difference and less to the physical properties of the leaf. The former method of energy dispersal disposes of the heat less rapidly than the latter, with a consequent drop in the rate of temperature loss, and also in 'K.'

2. At lower temperature differences under still air conditions the removal of air from around the cooling tissue by convection currents is much less rapid and a decreased rate of cooling results.

SUMMARY.

1. Thermal emissivity and not transpiration is the agent which prevents overheating of plant tissue.

2. The proportion of available energy absorbed in transpiration gives no indication of its cooling value.

3. For temperature differences greater than 3 C.° the rate of cooling of a plant tissue is a linear function of the temperature difference between the leaf and air, under still air conditions.

4. The effect of desiccation is to increase the emissivity of the tissue.

5. A method is described for finding the thermal emissivity of the tissue by observing its rate of cooling under known conditions.

6. The rates of temperature loss and constant 'K' have been calculated for *Liriodendron tulipifera*, *Bryophyllum calycinum*, *Mesembryanthemum crystallinum*, *Echeveria weinbergia*, and *Cereus*.

7. A comparison of the constants of proportionality between rates of cooling for any two plants gives a comparison of the rates themselves. Thus the plants can be grouped according to their respective emissivities.

8. The thermal emissivity of *Liriodendron tulipifera* was determined and compared to the value found by Brown and Wilson for this species. The result was 17% less than that of Brown and Wilson.

9. A formula was derived for finding temperature of a tissue of known emissivity and initial temperature, after the interval of any number of minutes. Conversely the length of time required for the tissue to fall in temperature any number of degrees can also be determined from the same formula.

10. The presence of vaseline upon the surface of a plant tissue decreases, *per se*, the emissivity of that surface.

LITERATURE CITED.

1. **Brown, H. T., and Escombe, F.** Researches in some of physiological processes of green leaves, with special reference to the interchange of energy between the leaf and its surroundings. Proc. Roy. Soc. London B, 76: 29–111. 1905.
2. **Brown, H. T., and Wilson, W. E.** On the thermal emissivity of a green leaf in still and moving air. Proc. Roy. Soc. London B, 76: 122–137. 1905.
3. **Clum, H. H.** The effect of transpiration and environmental factors on leaf temperatures. Amer. Jour. Bot. 13: 194–231. 1926.
4. **McDougal, D. T.** How plants endure heat and cold. Gard. Mag. 36: 152–154. 1922.
5. **Miller, E. C.** Plant Physiology. 900 pp. New York. 1931.
6. ———. Unpublished data, Kans. Agr. Expt. Sta. 1928.
7. **Miller, E. C., and Saunders, A. R.** Some observations on the temperature of leaves of crop plants. Jour. Agr. Res. 26: 15–43. 1923.
8. **Shull, C. A.** Transpiration as energy dispersal. School Sci. and Math., Vol. 19: 1–7. 1919.
9. **Spoehr, H. A.** Photosynthesis. 393 pp. New York. 1926.
10. **Transeau, E. N.** Accumulation of energy by plants. Ohio Jour. Sci. 26: 1–10. 1926.

AVIAN TUBERCULOSIS IN FREE WILD BIRDS.

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The occurrence of avian tuberculosis in domestic birds and wild birds in captivity has been reported and reviewed frequently [Hastings and Halpin (1913), Van Es and Schalk (1914), Gallagher (1921), and Mitchell and Duthie (1929)].

Van Es and Schalk (1914) "observed a well-marked case of tuberculosis in a sparrow which had access to an infected poultry yard." They cite a tuberculous sparrow mentioned by Metschnikoff (1888), but it is not clear whether this was a bird in captivity. In 1929 Mitchell and Duthie reported avian tuberculosis in *Corvus b. brachyrhynchos*, from western Ontario where the birds were dying in large numbers. In a private communication (1933), Dr. Mitchell very generously communicated the following material: "In addition to this preliminary report considerable work has been carried out which has never been published. We examined over six hundred common crows. . . . Approximately 8% of the crows captured were tuberculous. . . . All . . . were wild. With one exception all cases were closely associated with the usual avian type of tuberculosis."

The writers wish to report a case of tuberculosis, apparently of the avian type, in a male eastern sparrow hawk (*Falco s. sparverius*) which was found dead, but still warm, on a street in Yellow Springs, Ohio, on January 20, 1933.

Upon dissection the breast muscles were seen to be greatly emaciated allowing the ridge of the carina to stand out prominently. The gizzard was empty and no fat was seen on the hawk's body. Imbedded in the lobes of the liver were many yellowish tubercles approximately 1.5 × 2.5–3.0 mm. in dimension. Smaller tubercles were found on the mesentries holding the convolutions of the intestine while on the intestine there were large flat irregular tubercles which reached diameters of 4.5 mm.

The lesions or tubercles from the liver approximated Pfander's second type of nodules (Van Es and Schalk, 1914). Sections of the necrotic liver material stained by the Ziehl-Neelsen method revealed acid-fast bacilli. Large numbers of

bacilli were in and surrounding the capsule but very few were in the central hyaline area.

Our results were checked through the kindness of Dr. Charles B. Morrey, Ohio State University, who wrote: "Dr. Fred Speer has stained material from the specimen of liver. . . . He finds acid-fast bacilli and there is no doubt that it is Avian Tuberculosis."

On the day after the diseased hawk was found, potato slants were streaked with material from a crushed liver tubercle. After one month smears taken from five cultures revealed only a small number of acid-fast bacilli on one slant. Subcultures were made in glycerin broth; complete results are not yet available.

Where this sparrow hawk contracted tuberculosis is problematical, possibly from the infected remains of domestic fowl disposed of carelessly or accidentally killed by automobile or interurban car along a nearby highway. Another possibility is that the disease might have been picked up from a wild or "domestic" mouse (Van Es and Schalk, 1914).

With increased investigation avian tuberculosis will probably be found in many other families of wild birds. Indicative of this is a statement in a letter from Milton B. Trautman, Bureau of Scientific Research, Ohio Conservation Division: "In the examination of some 1,000 wild birds, . . . I have found very little of what I considered tuberculosis, . . . In several cases I have seen these yellow lesions or tubercles in the mesentries and liver and in one or two cases have also found tubercles on the kidneys."

BIBLIOGRAPHY.

Gallagher, B. A. 1921. Tuberculosis of Fowls. U. S. Dept. of Agriculture, Farmers' Bulletin No. 1200, 6 pp.

Hastings, E. G., and J. G. Halpin. 1913. Avian Tuberculosis. Research Bulletin 28, University of Wisconsin Agricultural Experiment Station. pp. 249–271.

Mitchell, Chas. A., and R. C. Duthie. 1929. Tuberculosis of the Common Crow. A Preliminary Study. Amer. Rev. Tuberculosis, Vol. 19, p. 134.

Van Es, L., and A. F. Schalk. 1914. Avian Tuberculosis. Bull. No. 108, North Dakota Agricultural Experimental Station. 94 pp.

Scientific Research.

It is said that a depression may end with the consumption of existing perishable goods, but prosperity is dependent on new developments which come only through research and its application. This volume weaves the threads of romance and adventure into the story of research, and makes of it a most fascinating tale. Each student intending to enter a life of experimental work should be required to read it.—L. H. S.

The Romance of Research, by L. V. Redman and A. V. H. Mory. x+149 pp. Baltimore, The Williams and Wilkins Co., 1933.

A UNIQUE RAISED BOG AT URBANA, OHIO.*

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Located just north of the Champaign County Fair Grounds at Urbana, Ohio, is a unique dome-shaped bog, covered with shrubby vegetation for the most part, in which the center is raised at least ten feet above the margins. An old road crosses the bog. I have been told that it was once the main thorofare from Urbana to Columbus. Horses and wagons passed over it, I suppose, the drivers never realizing that a mat of fibrous roots less than one foot thick was all that held them over a body of water twelve feet in depth.

Raised bogs, called "high moors" and "Hochmoore" in foreign literature, have long been known throughout Europe. N. S. Shaler is credited by Nichols with being the first to call attention to these peculiar swamps in North America, in 1888–89. Those which Shaler observed were "mostly limited to the eastern portion of Maine, near the shores of the Bay of Fundy," but some of lesser magnitude were reported for New Hampshire, northern Michigan, and Minnesota. Similar bogs, with centers about 13 feet above their margins, have been reported in the province of New Brunswick by Ganong (1897).

Nichols (1919) described bogs of this type encountered in Maine, in which the elevation of the center above the margin varied from 2 or 3 feet to as high as 18 feet (e. g., Denbo Heath, covering several square miles in area). He asserts: "(1) that in the state of Maine raised bogs, in so far as they constitute a distinctive swamp type, are virtually restricted to the proximity of the seacoast; and (2) that in other portions of New England and of the eastern United States this type of bog is practically absent, although in occasional swamps it is possible to detect a slight elevation of the surface above the level of permanent ground water."

Warming (1909) has summarized concisely the characteristic features of "Hochmoore." They owe their development to the growth of sphagnum mosses which absorb water that falls in the form of rain or snow. Accordingly they are confined to

*Papers from the Department of Botany, the Ohio State University, No. 333.

regions of high precipitation and high humidity. They are called raised bogs or climbing bogs because they are commonly much higher near their centers than at their margins. According to Warming, their waters are practically free from salts or lime, and they are covered with bog mosses, chiefly species of *Sphagnum*, and with shrubby heaths. Nowhere in the literature can we find a reference to raised bogs in which the water contains an abundance of calcium salts and in which the dominant vegetation is other than sphagnum mosses and shrubby heaths, but such is the Urbana bog.

The presence of this unique habitat was first brought to the writer's attention in June, 1926, by Mr. Roscoe Franks, who realized its unusual character. It has lately been visited many times, in company with other botanists and classes from the Ohio State University.

The main portion of the bog occupies a lot eight or ten acres in extent, belonging to the McDonald Sisters in Urbana. Water which flows from the bog and from springs in the vicinity is used by the Urbana Tool and Die Co. to supply their reservoir, less than a quarter of a mile to the west. The water is distinctly alkaline, and the streams are usually choked with species of *Chara* and with watercress (*Radicula nasturtium-aquaticum* (L.) Britt. & Rendle. *Zannichellia palustris* L. and *Batrachium circinatum* (Sibth.) Rchb. occur in the streams and ditches, along with filamentous algae, which are being studied by F. B. Chapman. The coldest waters issuing from the bog on July 24, 1932, were at a temperature of 55° F., according to Chapman's data.

The dominant vegetation over the raised bog consists of a dense growth of shrubby cinquefoil (*Dasiphora fruticosa* (L.) Rydb.) Elderberry bushes (*Sambucus canadensis* L.) are scattered among the smaller shrubs, but are not nearly so numerous as the cinquefoils. Swamp rose (*Rosa carolina* L.) is also an important member of the plant association on the bog. Tufts of sedges, (principally *Carex emoryi* Dew.) grow everywhere on hummocks created by the crowns of shrubby cinquefoil. In some places, which are better drained, the sedges are replaced by Kentucky blue grass (*Poa pratensis* L.). Purple-stemmed Angelica (*Angelica atropurpurea* L.), swamp-milkweed (*Asclepias incarnata* L.), and evening primrose (*Oenothera biennis* L.) are perhaps the commonest large herbaceous plants and grow luxuriantly in this bog habitat.

FIG. 1. (Upper.) Stream choked with water-cress in June, 1926. Urbana Raised Bog.

FIG. 2. (Lower.) A view of the raised bog at Urbana, Ohio, October 7, 1931.

On the black peaty soil underneath the shrubs are small herbaceous plants, including crested shield-fern (*Dryopteris cristata* (L.) Gr.) small-flowered agrimony (*Agrimonia parviflora* Ait.) and several kinds of bryophytes and lichens. Two species of mosses have been identified by C. H. Coles as *Anomodon rostratus* (Hedw.) Schimp. and *Tortella caespitosa* (Schwaeg.) Linn. No sphagnum has been found here.

A preliminary traverse of the bog has been made by J. C. Kuenzel and O. D. Diller of the Central States Forest Experiment Station staff. The margins of the bog have an elevation of approximately 1050 feet above sea level, while the datum for the highest point is 1061. A few yards to the north of this point, a water-pipe has been driven into the peat. Although the top of the pipe is at least one foot above the ground, a steady flow of clear cold water flows out of the top, showing that a head of water pressure is maintained beneath the bog.

Test borings have been made by E. M. West, now Assistant Professor of Botany at Louisiana State University. A boring at the 1060-foot contour shows that 12 feet of water lies beneath the dense mat of roots which permeate the soil. It was there that the old road, previously referred to, crossed the bog. The road was formed by spreading gravel over the black peaty soil and is now marked by a luxuriant growth of blue-grass. Other introduced plants have been seen, including an apple tree, a peach tree, a few osage orange trees and a clump of *Ornithogalum umbellatum* L. A single specimen each of "buffalo currant" (*Ribes odoratum* Wendl.) and Japanese barberry (*Berberis thunbergii* D.C.) grow beside the old road bed.

Comparatively few boreal relics of the Northern Evergreen Forest Center are present in the bog flora. They include the following species:

Dasiphora fruticosa (L.) Rydb. (*Potentilla fruticosa* L.)
Carex emoryi Dew.
Galium boreale L.
Vagnera stellata (L.) Mor.
Anticlea elegans (Pursh.) Rydb.

Many species, characteristic of marshy areas in general of the northeastern states and Canada, are included, as follows:

Dryopteris thelypteris (L.) Gr.
Dryopteris cristata (L.) Gr.
Onoclea sensibilis L.
Glyceria nervata (Willd.) Trin.
Typha latifolia L.
Caltha palustris L.
Carex hystricina Muhl.
Carex lurida Wahl.
Scirpus validus Vahl.
Scirpus americanus Pers.
Scirpus atrovirens Muhl.
Rosa carolina L.

Rumex britannica L.
Alsine longifolia (Muhl.) Britt.
Lythrum alatum Pursh.
Solanum dulcamara L.
Salix discolor Muhl.
Dracocephalum virginianum L.
Pedicularis lanceolata Mx.
Eupatorum purpureum L.
Cirsium muticum Mx.
Viola papilionacea Pursh.
Impatiens biflora Walt.
Galium tinctorium L.
Urtica dioica L.
Lycopus americanus Muhl.
Lobelia syphilitica L.
Senecio aureus L.
Eupatorum perfoliatum L.
Eupatorum maculatum L.

Several species of the Tall-grass Prairie Center are particularly evident in the flora of the raised bog. Among them are the following:

Andropogon furcatus (Muhl.)
Andropogon scoparius Michx.
Sorghastrum nutans (L.) Nash.
Filipendula rubra (Hill.) Rob.
Apocynum cannabinum L.
Koellia virginiana (L.) MacM.
Solidago ohioensis Ridd.
Allium cernuum Roth.
Steironema quadriflorum (Sims.) Hitchc.
Meibomia canadensis (L.) Ktz.
Mesadenia tuberosa (Nutt.) Britt.
Silphium trifoliatum L.
Rudbeckia hirta L.
Liatris spicata (L.) Willd.

In the swampy fields below and surrounding the raised bog a number of other interesting marsh species may be found, such as the following:

Valeriana edulis Nutt.
Lathyrus palustris L.
Triglochin maritima L.
Parnassia caroliniana Mx.
Solidago riddellii Frank.
Lobelia kalmii L.

A few weedy species also grow among the bog shrubs, among them the following:

Barbarea stricta Andrz.
Cerastium vulgatum L.
Nepeta hederacea (L.) Trevisan.
Convolvulus sepium L.
Dipsacus sylvestris Huds.
Erigeron ramosus (Walt.) B. S. P.
Asclepias syriaca L.
Parthenocissus quinquefolia (L.) Planch.
Leontodon taraxacum L.
Cirsium arvense (L.) Scop.
Lactuca canadensis L.

The origin of the raised bog at Urbana can be clearly understood only if we take into account some important historical factors. An early continental glacier (Wisconsin?) invaded the Urbana region. Two main lobes of the glacier, the Miami lobe to the west and the Scioto lobe to the east, were formed by the Campbell Hill promontory ten miles north of Urbana. The ice must have stagnated there for a long time, because deep deposits of gravel and boulders compose the lateral moraines on either side of the Mad River Valley. These deposits serve as

reservoirs of water and form the principal source of headwaters in the Mad River drainage.

The glacial drift at Urbana overlies limestone to a depth of 150 feet (Leverett, 1902). Land 1.7 miles east of the raised bog rises 130 feet higher than the margins of the bog, in a region of kame topography. Flowing wells or artesian springs are found in several places. It was around one of these artesian springs that the raised bog at Urbana developed. Supported by hydrostatic pressure below and held together by a mass of roots above, the bog shrub association of *Dasiphora fruticosa* exists here as a relic of an earlier type of vegetation which once occurred throughout the region. In spite of present climatic conditions, the constancy of water supply from artesian sources has maintained alkaline bog vegetation in a region where the prevailing natural vegetation is oak-hickory forest and tall-grass prairie.

REFERENCES CITED.

Shaler, N. S. General account of the Fresh-water Morasses of the United States, with a Description of the Dismal Swamp District of Virginia and North Carolina. 10th Ann. Rept. U. S. Geol. Surv., Part I, pp. 255–339; reference on p. 286. 1888–89.

Ganong, W. F. Upon Raised Peat Bogs in the Province of New Brunswick. Trans. Royal Soc. Can., Second Series, Vol. III, Sect. IV, pp. 131–163. 1897.

Leverett, Frank. Glacial Formations and Drainage Features of the Erie and Ohio Basins. U. S. Geol. Surv. Mon. 41, pp. 802; references on pp. 313–314. 1902.

Warming, Eugene. Oecology of Plants. Authorized English Translation. First Edition. See pp. 200–205. Oxford University Press. 1909.

Nichols, G. E. Raised Bogs in Eastern Maine. Geog. Rev. Vol. VII, No. 3, pp. 159–167. 1919.

Geology of California.

To completely cover the geology of California in one volume is impossible. Reed has wisely touched only on the pre-Mesozoic geology and expended most of his labor on attempting to explain and clarify the geology from the base of the Triassic on, with especial emphasis on the Tertiary. This would appear to be an extremely wise course to take especially as his profession (Chief Geologist of the Texas Oil Company of California) has so ably fitted him to explain the complicated and often poorly correlated and identified Tertiary rocks of California. The work is enhanced with paleogeographic maps of the various periods from the Cretaceous to the recent. An appendix of important geographic names, an authors index, and a subject index are supplied. The use of the term "micro-photograph" for photomicrograph is unfortunate but still a common usage. It is to be regretted that a fairly large scale geologic map could not be included as it would be of great value.—Willard Berry.

Geology of California, by R. D. Reed. xxiv+355 pp. Tulsa, American Association of Petroleum Geologists, 1933.

STUDIES IN THE BIOLOGY OF THE LEECH. I.*

The Subepidermal Nerve Plexus of the Leech *Haemopis marmoratis* (Say).

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Ohio State University.

INTRODUCTION.

A subepidermal network of nerve fibers similar to the one I have observed in the leech *Haemopis marmoratis* (Say), was observed in the epidermis of the earthworm by Retzius (1892), Smirnow (1894), Langdon (1895), Smallwood (1923) and Hess (1925). The subepidermal nerve plexus has not been previously described for the Hirudinea.

The purpose of this paper is to present a description of the subepidermal nerve plexus for the leech *Haemopis marmoratis* (Say), and the relation of this plexus to the muscles of the body wall, the epidermis and the central nervous system.

In a study of the nervous and muscular systems of the leech a definite nerve plexus was evident in the region between the bases of the epidermal cells and the basement membrane. A further investigation disclosed the nature of this plexus.

MATERIALS AND METHODS.

For the experimental work it was found desirable to use a single species of leech. The members of this group differ in habits and nerve patterns as well as in the nature of the integument and connective tissue. *Haemopis marmoratis* (Say) was selected because of its abundance in this locality (Columbus, Ohio). This species was further useful since it is a leech of large size and can be kept for considerable time in the laboratory.

N. Chandler Foote's modification of the Bielchowsky's ammoniacal silver method was used in the preparation of nervous tissue. Gross dissection with the aid of the Barrows' binocular bridge and 2% osmic acid were profitable.

*This is the first in a series of studies devoted to the anatomy and behavior of the leech.

THE SUBEPIDERMAL NERVE PLEXUS.

This part of the nervous system is composed of anastomosing nerve fibers which form a network in the region between the bases of the epidermal cells and the basement membrane. Branches from this plexus innervate the epidermis as well as the muscle layers. This network of nerves represents structurally, as well as physiologically, a true nerve plexus. This plexus differs from the other phases of the nervous system in that it shows no signs of the characteristic metamerism of the animal. This network surrounds the entire body. There are four regions of concentration of the subepidermal network located as follows: two regions just lateral to the mid-dorsal line and two just lateral to the mid-ventral line. (See Figure 2.)

From the epidermal sense cells arise neurofibrillae which extend into the subepidermal plexus. (Whitman, 1888.) From the subepidermal nerve plexus both intercellular and intracellular nerve fibers extend into the epidermis. From this plexus nerve fibers also extend inward innervating regions supplied by branches of the peripheral nerves. The subepidermal region is connected with the central nervous system through nerve trunks extending between the ganglia in the cord and the region of the epidermis. Branches of these epidermal nerve trunks innervate the subepidermal plexus as well as the epidermal cells. These nerve trunks are most obvious in the leech in the regions of the concentration of the subepidermal nerve plexus. (See Figures 2 and 3.)

From these observations and unpublished experimental data it is obvious that a definite relationship exists between the subepidermal nerve plexus, the muscles of the body wall, and the central nervous system. It is only on the basis of this deduction that certain expressions of behavior can be adequately explained. (Details of experimental proof and explanation will follow in a later number of this publication.)

The accompanying diagrams and photomicrographs will giver a clearer conception of this system in the leech.

SUMMARY.

(1) A subepidermal nerve plexus is present in the leech.

(2) The subepidermal nerve plexus is a network of anastomosing nerve fibers between the epidermal cells and the basement membrane.

(3) The subepidermal network surrounds the entire body.

(4) There are four regions of concentration of the subepidermal plexus: two dorso-lateral and two ventral-lateral.

(5) This system is supplied by fibers directly from the sense cell bodies in the epidermis.

(6) From this system nerve fibers extend directly to the muscles of the body wall as well as to the central nervous system.

(7) The subepidermal plexus serves as a reflex system of the body wall outside of the central nervous system.

BIBLIOGRAPHY.

Bourne, A. G. 1884. Contributions to the Anatomy of the Hirudinea. Q. J. Micr. Sci. XXIV, pp. 419–508.

Fortuyn, A. E. B. D., and Kappers, C. U. A. 1920. Vergleichende Anatomie des Nervensystems, pp. 99–116.

Hess, Walter N. 1925. The Nervous System of the Earthworm, Lumbricus terrestris. Jour. Morph & Physiol., Vol. 40, No. 2.

Hubrecht, A. A. W. 1880. The Peripheral Nervous System in Paleo- and Schizo-Nemertinii. Q. J. Micro. Soc., Vol. 20, pp. 431.

Langdon, Fanne E. 1895. The Sense Organs of Lumbricus agricola. Jour. of Morphology, Vol. 11, pp. 194–235.

Retzius. 1891. From Kappers and Fortuyn.
1900.

Sanchez, D. 1909. El Sistema Nervioso De Les Hirudineos. Trajabos del Laboratorio de Investigaciones Biologicas Del La Universidad De Madrid. Pub. por. S. R. Cajal. T. VII.
1912. Continuacion de (above). Tomo X.

Smallwood, W. M. 1923. The nerve net in the earthworm. Proc. Nat. Acad. Sc. Washington, Vol. 9, pp. 95–100.

Smirnow. 1894. From Kappers and Fortuyn.

Von Lehossek. 1895. From Kappers and Fortuyn.

Whitman, C. O. 1889. On the Embryology of Clepsine. Q. J. Micr. Sci., XVIII, pp. 215–315.
1888. J. Morph. II, pp. 586–599.
1889. J. R. Micr. Soc., pp. 516–518.

EXPLANATION OF PLATE.

FIG. 1. A camera lucida drawing, ×80, of a ventro-lateral concentration of the subepidermal nerve plexus. Note the inter-muscular as well as the subepidermal ramifications of these fibers.

FIG. 2. A drawing of a cross-section illustrating the arrangement of the muscles of the body wall and showing the distribution of the subepidermal nerve plexus.

FIG. 3. A photomicrograph, × 250, of a dorso-lateral concentration of the subepidermal and inter-muscular nerve plexus.

KEY: C. Circular muscle, E. Epidermis, L. Longitudinal muscle, N. Nerve trunk, S. Subepidermal nerve fibers. Note the intermuscular ramifications of the subepidermal nerve fibers.

NOTE: The technique employed in securing and staining nervous tissue was of such a nature as to insure the staining of such tissue through specific nerve stains.

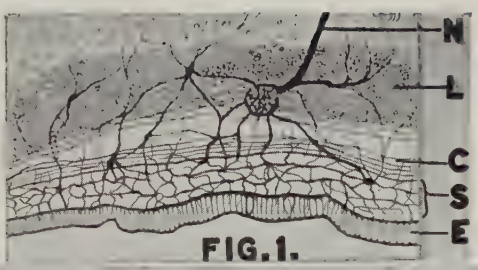

FIG. 1.

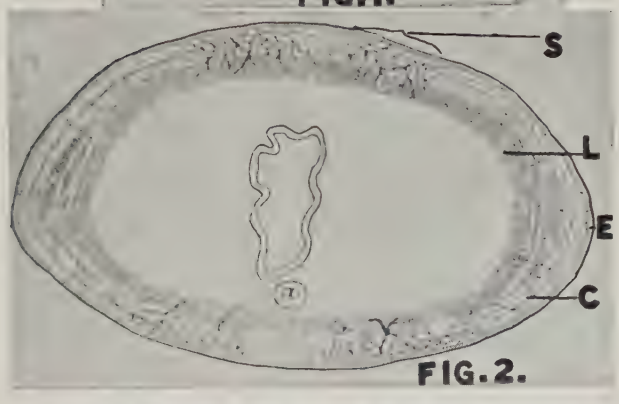

FIG. 2.

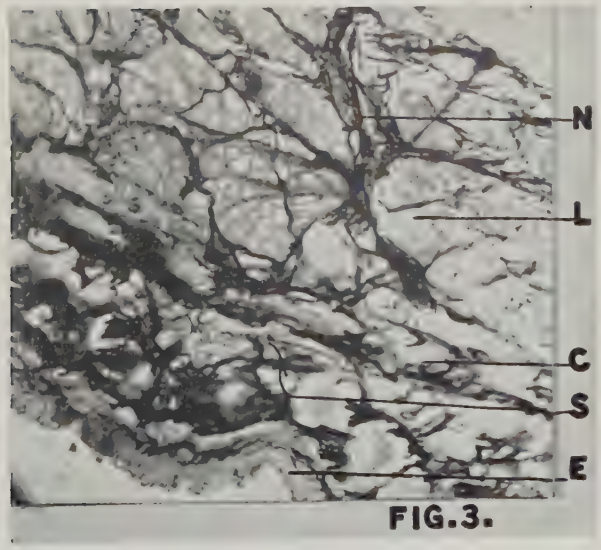

FIG. 3.

A NEW SPECIES OF LERNAEA (PARASITIC COPEPODA) FROM THE GOLDFISH.

WILBUR M. TIDD,
Ohio State University.

In the summer of 1930 some goldfish were sent to the author for examination by the proprietor of a goldfish farm in the southern part of Ohio. Examination revealed the presence of a number of parasitic copepods anchored firmly in the flesh of the fish. These parasites undoubtedly belong in the genus Lernaea, but a subsequent search of the literature has not revealed a species of this group to which they may be referred.

These parasites were first noted in the goldfish ponds in the summer of 1929. In 1930 three of the ponds were badly infested and the proprietor stated that almost every fish taken from them carried one or more of the parasites. In 1931 the infestation decreased considerably. Throughout the summer of 1932 parasites were found from time to time upon the fish and the degree of infestation roughly approximated that of the preceding summer.

This is the second time Lernaea has been reported as occurring upon goldfish. Enders and Rifenburgh (1928) reported a similar infestation at one of the large fish hatcheries in Indiana. They gave a brief description of the parasite with a few of the early stages in its life history. However, they did not refer it to any known species or describe it as a new one.

Lernaea carassii,[1] new species.

The type and paratypes of this species have been deposited in the United States National Museum and are recorded under catalogue numbers 67460 and 67461 respectively.

Female.—This species is characterized by the number and arrangement of the horns which arise from the cephalothorax and serve to anchor the parasite in the flesh of its host. The dorsal pair of horns (Fig. 1) fork distally into two unequal rami, the longer of the two continues at a slight angle to the

[1]Named after its host, Carassius auratus.

base of the horn, while the shorter one bends posteriorly and forms an angle with the first. These rami may be blunt or sharply pointed at their free ends. Occasionally a specimen is found in which one of the shorter rami is merely a small tubercle, making the dorsal horns unsymmetrical. The ventral horns are conical, slender, and sharply pointed. They usually curve toward the ventral surface of the body.

The free-thorax (Fig. 1) is slender in the region of the second pair of legs and gradually enlarges posteriorly. It is obscurely segmented and usually flexed in the region where it projects from the flesh of its host. Reference to the position of the egg sacks, pregenital prominence, and feet shows that the free thorax has undergone a rotation to the right, upon its longitudinal axis, thus carrying the egg sacks through an angle of approximately 90 degrees. Wilson (1917a) explained this phenomenon of twisting, or torsion, as being produced by the parasite twisting upon its longitudinal axis as it burrowed into the tissue of its host.

The pregenital prominence is usually well marked, simple or bilobed. The abdomen is conical, slightly upturned, and ends in two small anal liminae, each of which is armed with a long plumose seta, with two non-plumose setae on the outer margin.

As shown in Figure 3 the head is circular with a blunt rostrum projecting from the center of the anterior margin. The first antennae contain four joints, the second joint being the longest, all joints are heavily armed with setae on the anterior margin. Second antennae two jointed, the first joint being much the longest and unarmed. The terminal one ends in a curved claw, one large seta and two short ones, with three short setae along the inner margin. Second maxillae with two claws of almost equal size; maxillipedes two jointed, the basal joint unarmed, the terminal joint ending in five claws, near the base of these is a blunt process and immediately behind this is located a second and somewhat smaller process which is tipped with a minute seta.

The five pairs of swimming legs (Figs. 4–8) are quite typical for those of the genus as described by Wilson (1917b). Each of the first four pairs of legs consists of a broad basopodite and two three-jointed rami, each of which is armed with spines and long plumose setae. The small fifth legs (Figs. 2 and 8) are located immediately posterior to the pregenital prominence.

The egg sacks are long and narrow, and about one-third the length of the body; each sack carries about one hundred and eighty eggs. When ready to hatch the eggs are of a light green color.

The color of specimens preserved in a solution of five percent formalin and ninety-five percent alcohol, mixed half and half, is a grayish white. Young living specimens are a pale green, while old living specimens are a light brown color, and are often covered with a dense growth of a stalked protozoon, among which algae collect, giving the parasite the appearance of a piece of dirty string adhering to the fish.

Twenty-five specimens have been used in the above description. The following measurements are averages derived from the measurement of ten specimens carrying egg sacks. Body length (excluding horns and egg sacks) 9.78 mm., range 7.33 to 11.70 mm.; greatest diameter 0.50 mm., range 0.40 to 0.81 mm.; length across dorsal horns from tip to tip 3.16 mm., range 1.74 to 4.05 mm.; length of ventral horn 0.50 mm., range 0.40 to 0.58 mm.; diameter of egg sacks 0.25 mm., range 0.18 to 0.36 mm.

While these parasites are usually attached at the base of the fins a number have been found attached in the nostrils and over practically all other parts of the body. The depth at which the cephalothorax is buried in the flesh varies from just beneath the integument to a penetration of the body wall by one of the horns in such a manner that it comes to lie inside the body cavity in contact with the viscera. Quite often the flesh of the fish surrounding the horns swells up in a tumor-like growth, and the horns working about in this lump keeps it irritated and bleeding. When the parasite is removed from the tumor-like growth the horns and head are often found to be covered with a tough tissue which is very difficult to remove.

Frog tadpoles have been found, at the goldfish farm, which were carrying the adult parasites. In the laboratory the tadpoles of Rana species have been parasitized by introducing them into aquaria with goldfish which were carrying the larvae of the copepods upon their gill filaments. The region of the tadpole's hind legs seems to be the chief point of attachment. The mortality among these parasitized tadpoles is unusually high.

REMARKS.

In the arrangement of the horns this species is quite similar to an African species, *Lernaea temnocephala* Cunnington (1914), which was found upon *Barbus bynni*, a fish of the River Nile. While we know nothing of the appendages or egg sacks of *temnocephala*, as the description of the species was based upon a single, poorly preserved specimen, still from the author's description of the disposition of the horns it would seem to be very similar to the species described above. However, the dorsal horns of *temnocephala* end in rounded lobes and are not pointed, also *temnocephala* is said by Cunnington to lack evidence of segmentation, and the abdomen is parallel with the body axis, characters which will hardly fit the specimens under consideration.

LITERATURE CITED.

Cunnington, W. A. 1914. Proceedings, Zoological Society of London, pp. 827–828; pl. I, Figs. 8, 9.

Enders, H. E., and Rifenburgh, S. A. 1928. A Preliminary Report on Lernaea, a Copepod Parasite on the Goldfish. Proceedings of the Indiana Academy of Science, Vol. 38, pp. 333–334.

Wilson, Charles Branch. 1917a. North American Parasitic Copepods belonging to the Lernaeidae with a Revision of the Entire Family. United States National Museum, Vol. 53, pp. 1–50.

1917b. The Economic Relations, Anatomy and Life History of the Genus Lernaea. United States Bureau of Fisheries, Vol. XXXV, pp. 165–198. Document No. 856.

EXPLANATION OF PLATE.

(All drawings were made from preserved specimens with the aid of the camera lucida.)

Fig. 1. Ventral view of female of Lernaea carassii.

Fig. 2. Ventral view of abdomen and pregenital prominence.

Fig. 3. Head and mouth parts: an^1, first antennae; an^2, second antennae; mx, second maxillae; mxp, maxillipedes; r, rostrum; h, head.

Figs. 4–8. First, second, third, fourth, and fifth swimming legs.

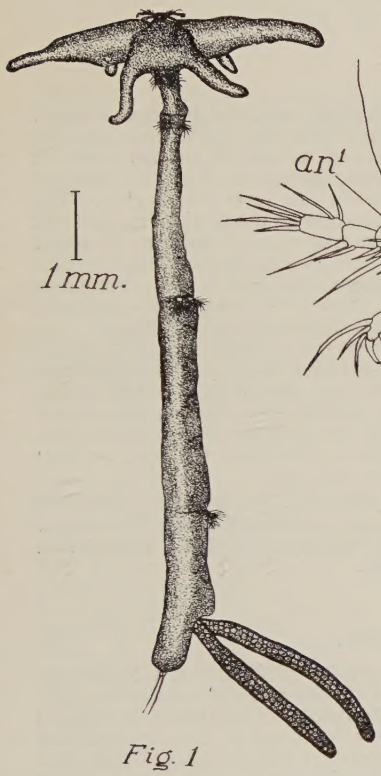

Fig. 1

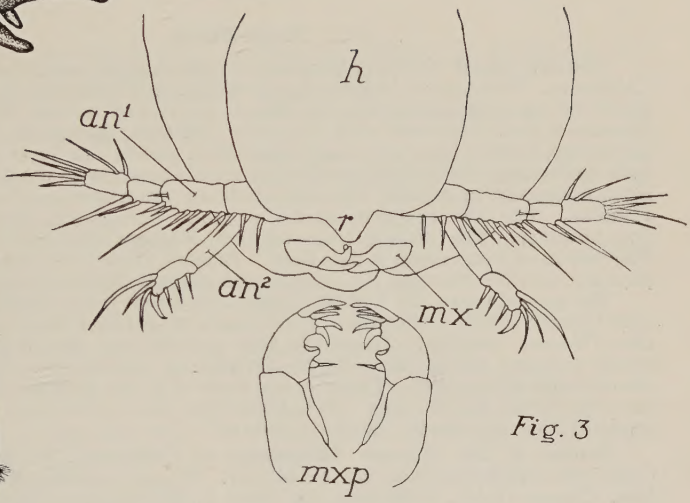

Fig. 3

Fig. 4

Fig. 2

Fig. 5

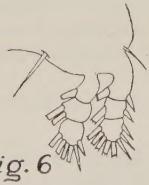

Fig. 6

Fig. 8

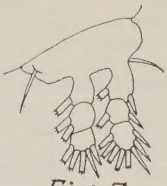

Fig. 7

BOOK NOTICES

Fossil Plants.

The first paper of this publication, by Dorf, deals with the Pliocene flora of California. From some 16 scattered localities in California, of Pliocene age, are described some 34 species of fossil plants, distributed among 26 genera, of which Quercus is most abundant with 5 species. Of these 34 species, 8 are too poor to determine, 5 have been previously described, and 21 are described as new. The beds containing these plant remains are most abundant in the lower Pliocene and least abundant in middle Pliocene with an intermediate abundance in upper Pliocene. The close relationship of the present flora is well shown, details differing, however. The change from uniform Miocene climate to the diversified Pliocene is well expressed in this flora. Already there is evidence of climatic and physical barriers between the eastern and western North American floras.

The second paper, by Webber, deals with woods from the Ricardo Pliocene of Last Chance Gulch, California. Five genera of petrified wood are described from this Pliocene locality. There are four generic and specifically determinable fossils and one which can only be determined generically. One undetermined dicotyledon is recorded. These fossils show that the Mohave Desert region was less arid during the Pliocene. It is hoped that this useful paper will lead to more work on Pliocene woods.—Willard Berry.

Studies of the Pliocene Paleobotany of California. I. Pliocene Flora of California, by Erling Dorf, pp. 1–112. II. Woods from the Ricardo Pliocene of Last Chance Gulch, California, by Irma E. Webber, pp. 113–134. Publication No. 412, Carnegie Institution of Washington, 1933.

Alcoholic Fermentation.

The author (see Arthur Harden, Nobel Laureate, 1929) has in this present edition more than doubled the size compared with the original edition of 1910. This book is apparently not "some brewers' handbook," but rather a detailed scientific discussion of the principles and theories involved in the fermentation processes. A general knowledge of Organic Chemistry, Physiological Chemistry or Bacteriology is essential to the proper understanding of this work. In addition to the description of the author's own investigation in this field there is included a very good survey of the work of other authors and an excellent bibliography (38 p.) of the literature up to the last of 1931.—Wallace R. Brode.

Alcoholic Fermentation, by Arthur Harden. Fourth edition, revised, 237 pp. New York, Longmans Green and Co., 1933.

Fresh-Water Algae.

American algologists have waited a long time for a comprehensive report on the algae of the United States that would be comparable to West and Fritsch: "British Freshwater Algae." Their patience has been rewarded in Smith's volume. The introduction discusses the ecology, methods of collecting, and recent evolutionary theories regarding the development of the freshwater algae. The morphology, reproduction, and taxonomy of all genera found in the United States, together with brief characteristics of the important species, occur. Each genus is illustrated by one or more original drawings. Amateurs will find especially helpful and comprehensive key to all genera, based on vegetative characters. The classes of algae discussed are Myxophyceae, Rhodophyceae, Heterokontae, Chrysophyceae, Bacillarieae, Chlorophyceae, Dinophyceae and Euglenophyceae. Students of the algae will find the book indispensable.—L. H. Tiffany.

The Fresh-water Alga of the United States, by Gilbert M. Smith. 716 pp., 449 illus. New York, the McGraw-Hill Co., 1933.

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